ADA079281

OFFICE OF NAVAL RESEARCH
800 North Quincy Street
Arlington, Virginia 22217

PROCESS VARIABLE DEPENDENCE AND INTERRELATIONSHIP BETWEEN AVALANCHE INJECTED AND RADIATION INDUCED CARRIER TRAPPING IN THERMAL OXIDES

Progress Report No. 1

1 April 1979 through 30 June 1979

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Fairchild Camera and Instrument Corporation
Research and Development Laboratory
4001 Miranda Avenue
Palo Alto, California 94304

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Prepared by   7/12/79

Approved by   Bruce E. Deal

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QUARTERLY STATUS REPORT NO. 1

Covering the Period 1 April 1979 through 30 June 1979

This is the first quarterly report on the ARPA sponsored
project titled "PROCESS VARIABLE DEPENDENCE AND INTER-
RELATIONSHIP BETWEEN AVALANCHE INJECTED AND RADIATION INDUCED
CARRIER TRAPPING IN THERMAL OXIDES." This program is carried
out in cooperation with the Naval Research Laboratory in
Washington, DC. Progress to date includes the modification
of our present computerized C-V analysis system to allow for
automated avalanche carrier injection measurements and data
reduction as well as the preparation of the first group of
samples to be used in the program.

Avalanche Carrier Injection System

The modifications proposed for our computerized C-V quasi-
static system to convert it to an automated avalanche carrier
injection trapping system have been carried out. Figure 1
shows a schematic of the system which is similar in principle
to that used by Don Young and co-workers at IBM* and which
includes a programmable signal source, a specially designed
amplifier, and a Boonton capacitance meter. All hardware
and software modifications have been carried out. Basic
system operation consists of the device under test being
switched from a capacitance/voltage measuring circuit to an
avalanche injection circuit. Typical injection times are 90
sec and flatband voltage shifts following injection are
measured in less than 3 sec. Average injected current is
kept constant by means of computer monitoring of the current
at 200 msec intervals and making the necessary changes in
the amplitude of the a.c. signal through the programmable
signal source. The output generated by the system consists
of plots of flatband voltage shift as a function of injection
time as shown in Fig. 2.

Sample Preparation--Dry O_2 Structures

N-type (111) silicon wafers, resistivity 0.2-0.3 Ω-cm, and
p-type (111) wafers resistivity 0.4-0.7 Ω-cm were oxidized
in dry O_2 at 900°, 1000°, and 1100°C to an oxide thickness
of approximately 800 Å. Following oxidation the wafers were
cooled in oxygen [fast pull (<3 sec), or slow pull (10
min)], or nitrogen (slow pull 2 min), or argon (slow pull 2
min). The oxide was then removed from the back of the
wafers, and Al-Cu-Si was deposited by cold flash on both
sides of the wafers. Metal dots (30 mils in diameter) were

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* We would like to acknowledge the information supplied to
us by D. Young on the IBM apparatus.

defined by photolithography and one half of each wafer
annealed in N_2 at 400°C for 10 min while the other half
received a post-metallization anneal in a 10% H_2 in N_2
ambient at 400°C for 10 min. Table I indicates the various
run numbers and the treatment received by each run.
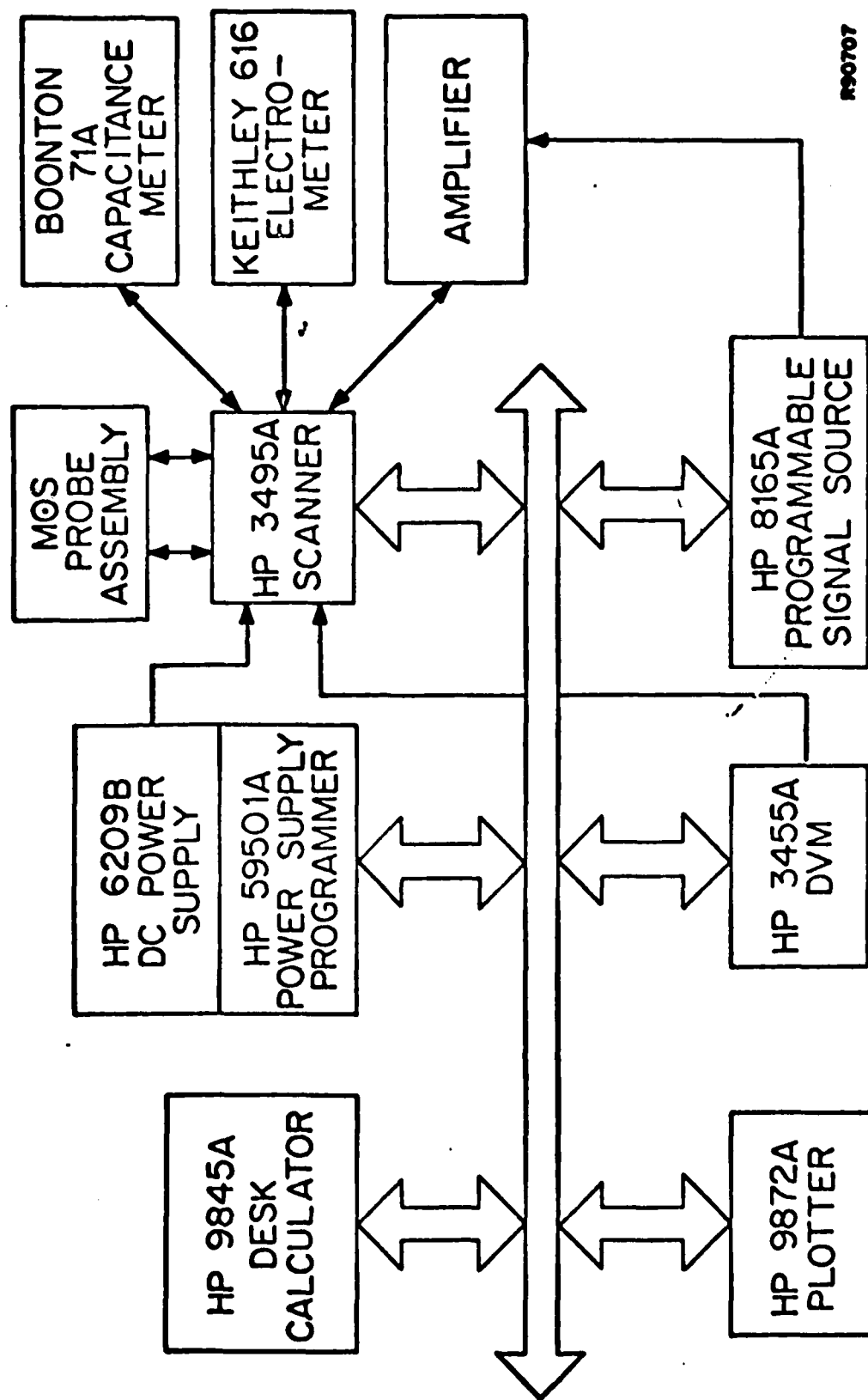
Measurements--Dry O_2 Structures

Due to the delay in the arrival of necessary equipment for
the measurement of avalanche injection trapping, only about
one third of the 900° and 1000°C samples have been measured
to date. Data dealing with flatband voltage shifts as well
as some data dealing with the increase in interface state
density levels as a result of avalanche injection will be
tabulated as soon as it becomes available.

Sample Preparation--H_2O Structures

N-type (111) samples, resistivity 0.2-0.3 Ω-cm, were oxidized
in H_2O at 900°C. Following oxidation the wafers were cooled
in H_2O (<30 sec pull) or in nitrogen or argon (<2 min pull)
and the back oxide removed. Remaining p- and n-type wafers
will be oxidized in the coming quarter.

The program schedule is enclosed and the program is essentially
on schedule. Measurements of dry O_2 samples should be con-
cluded at the end of next quarter as well as the preparation
of the H_2O structure as outlined in the program schedule.

BOONTON 71A CAPACITANCE METER

KEITHLEY 616 ELECTRO-METER

AMPLIFIER

MOS PROBE ASSEMBLY

HP 3495A SCANNER

HP 8165A PROGRAMMABLE SIGNAL SOURCE

HP 6209B DC POWER SUPPLY

HP 59501A POWER SUPPLY PROGRAMMER

HP 3455A DVM

HP 9845A DESK CALCULATOR

HP 9872A PLOTTER

R90707

Fig. 1. Schematic of computerized system for avalanche injection and trapping of carriers in thermal oxides.

COMPUTERIZED C-V ANALYSIS SYSTEM

OPERATOR R. RAZOUR
DATE
TIME 8:37 PM
WAFER # TR-3-TEST
N-TYPE (111)

PULL COND
H₂ ANNEAL
OXIDE THICK (Å) 800
GATE MATERIAL AL

C_{MAX} (H-F)   221.35 pf
C_{MIN} (H-F)   115.96 pf
C_{MAX} (Q-S)
DOPING (cm⁻³) 2.28E+16
V_{FB} (Volts)   -.920
V_{TH} (Volts)   -3.330
Q_{SS}/q (cm⁻²)
N_{ot} (cm⁻² -eV) 2.86E+11
(AT MIDGAP)

Final

Initial

C/C_0 1.0 0.8 0.6 0.4 0.2

-10   GATE VOLTAGE (volts)   10

FLAT BAND VOLTAGE SHIFT (volts) 5 4 3 2 1 0

0   1000   2000   3000   4000   5000
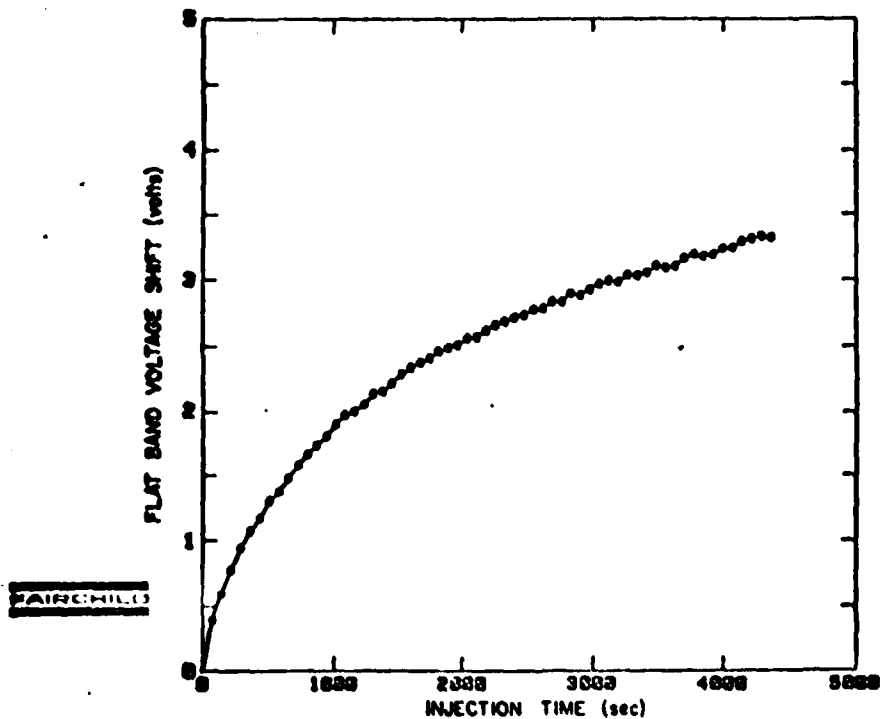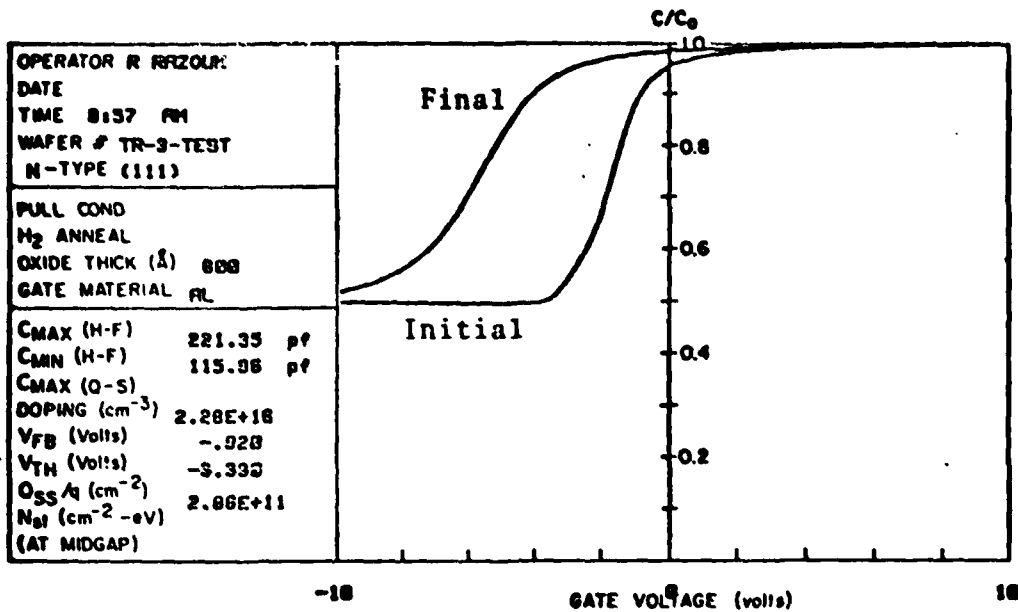INJECTION TIME (sec)

Fig. 2.   Typical output from the automated avalanche carrier injection and trapping system.

TABLE I

Values of Fixed Oxide Charge (Q_{ss}) and Interface State Density (N_{st}) For N-Type (111) Silicon Wafers Oxidized in Dry Oxygen

Run No.	Oxidation Temp. (°C)	Ox./ Anneal Ambient	Ox./ Anneal/Cool Time*(min)	Cool Condition**	Oxide Thickness (μm)	Q_{ss}/q ($10^{11}/cm^2$)	Midgap N_{st} ($10^{11}/cm^2$-eV) N_2 Anneal	Midgap N_{st} ($10^{11}/cm^2$-eV) H_2 Anneal
TR-1	900	O2/-	300/0/0	O2 FP	0.079			
TR-2	::	O2/-	300/0/10	O2 SP	0.081			
TR-3	::	O2/N2	300/10/2	N2 SP	0.079			
TR-4	::	O2/Ar	303/10/2	Ar SP	0.081			
TR-5	1000	O2/-	84/0/0	O2 FP	0.081			
TR-6	::	O2/-	84/0/10	O2 SP	0.087			
TR-7	::	O2/N2	84/10/2	N2 SP	0.084			
TR-8	::	O2/Ar	84/10/2	Ar SP	0.084			
TR-9	1100	O2/-	28/0/0	O2 FP	0.079			
TR-10	::	O2/-	28/0/10	O2 SP	0.088			
TR-11	::	O2/N2	28/10/2	N2 SP	0.081			
TR-12	::	O2/Ar	28/10/2	Ar SP	0.082			

* oxidation time/anneal time in N_2 or Ar/Pull time

** O_2 FP = fast pull (<3 sec) in O_2

O_2 SP = slow pull (10 min) in O_2

N_2 SP or Ar SP = slow pull (2 min) in N_2 or Ar

RRR 6/21/79

PROGRAM SCHEDULE

	1979									1980	
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB

MILESTONES

I-EVALUATION TASKS

- Prepare Dry O_2 Structures at:
  - 900°C
  - 1000°C
  - 1100°C

  [Four runs per temp; cool cond.-O_2 PP, O_2 SP, Ar SP, N_2 SP]

- Evaluate Dry O_2 Structures:
  - 900°C
  - 1000°C
  - 1100°C

- Prepare H_2O Structures at:
  - 900°C
  - 1000°C
  - 1100°C

  [Three runs per temp; cool cond.-H_2O PP, Ar SP, N_2 SP]

- Evaluate H_2O Structures:
  - 900°C
  - 1000°C
  - 1100°C

- Prepare HCl/O_2 Structures at:
  - 1000°C

  [Two runs; cool cond.-Ar SP, N_2 SP]

- Evaluate HCl/O_2 Structures:
  - 1000°C

II-DELIVERY SCHEDULE

- Test (R^2) Structures
  - 24 Dry O_2
  - 18 H_2O
  - 4 HCl/O_2
- Reports
  - Progress
  - Interim
  - Final